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Cockpit accommodation assessment of the Bell 412CF helicopter

Pierre Meunier

Defence R&D Canada
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In conducting the research described in this report, the investigators adhered to the policies and procedures set out in the Tri-Council Policy Statement: Ethical conduct for research involving humans, National Council on Ethics in Human Research, Ottawa, 1998 as issued jointly by the Canadian Institutes of Health Research, the Natural Sciences and Engineering Research Council of Canada and the Social Sciences and Humanities Research Council of Canada.

Abstract

The Bell 412CF helicopter was recently added to the training curriculum to teach multi-engine, multi-crew and IFR (Instrument Flight Rules) skills. Nine Bell 412CF helicopters were produced from existing CH-146 Griffons, which posed technical challenges. One such compromise was the routing of large bundles of electrical wires on either side of the main instrument panel. Some of these wire bundles were routed very close to the rotor pedals causing concerns about potential interference with their operation.

The results of this study indicate that the routing of the wire bundles is unlikely to impede operation of the rotor pedals when operated from the right seat in the worst-case situation, namely with the pedal carriage fully forward with full-left pedal actuation with Size 13 winter boots. Overall, the results obtained from this small sample of student pilots indicate a fairly accommodating cockpit in terms of stick authority. Although individual students will experience differing degrees of stick authority, the vast majority should be able to find a seat position that will allow ample range of motion to carry out course syllabus manoeuvres.

Résumé

L'hélicoptère Bell 412CF a récemment été ajouté au programme de formation au pilotage des appareils multi-moteurs, aux équipages composés de plusieurs pilotes et au vol IFR. Neuf hélicoptères Bell 412CF ont été produits à partir d'hélicoptères *Griffon*, ce qui a posé des défis sur le plan technique. Un des défis en question était d'acheminer de volumineux faisceaux de câbles de chaque côté du tableau de bord principal. Certains de ces faisceaux de câbles ont été acheminés à proximité du palonnier, et l'on était préoccupé par le fait qu'ils puissent gêner le fonctionnement des pédales.

Les résultats de la présente étude indiquent que, même si cette solution n'est pas idéale, l'acheminement des faisceaux de câbles ne gênera fort probablement pas le fonctionnement du palonnier lorsqu'il est utilisé par le pilote assis dans le siège droit, et ce, dans les pires conditions, c'est-à-dire que le palonnier se trouve tout à fait en position avant, que la pédale gauche est complètement enfoncée et que le pilote porte des bottes d'hiver de pointure 13. Dans l'ensemble, les résultats obtenus auprès d'un petit échantillonnage d'élèves-pilotes indiquent que l'aménagement du poste de pilotage est satisfaisant pour ce qui est de maîtriser le manche. Même si la maîtrise du manche varie d'un élève-pilote à l'autre, la plupart des pilotes devraient pouvoir s'asseoir assez confortablement dans leur siège pour exécuter sans entrave tous les mouvements nécessaires aux manœuvres comprises dans le programme de cours.

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Executive summary

Cockpit accommodation assessment of the Bell 412CF helicopter:

Pierre Meunier; DRDC Toronto TM 2009-160; Defence R&D Canada – Toronto; December 2009.

Introduction or background:

The Bell 412CF helicopter was recently added to the training curriculum to teach multi-engine, multi-crew and IFR (Instrument Flight Rules) skills. Nine Bell 412CF helicopters were produced from existing CH-146 Griffons, which posed technical challenges. One such compromise was the routing of large bundles of wires on either side of the main instrument panel. Some of these electrical wire bundles were routed very close to the rotor pedals causing concerns about potential interference with their operation.

The primary purpose of this study was to investigate the potential interference of the wire bundles with the operation of the rotor pedals for a range of operator sizes. A second objective was to determine the limits of accommodation of the cockpit with respect to stick authority.

Results:

The results of this study indicate that the routing of the wire bundles is unlikely to impede operation of the rotor pedals when operated from the right seat in the worst-case situation, namely with the pedal carriage fully forward with full-left pedal actuation with Size 13 winter boots. Overall, the results obtained from this small sample of student pilots indicate a fairly accommodating cockpit in terms of stick authority. Although individual students will experience differing degrees of stick authority, the vast majority should be able to find a seat position that will allow ample range of motion to carry out course syllabus manoeuvres.

Significance:

The presence of wire bundles so close to the rotor pedals did not appear to impede operation of the rotor pedals when operated from the right seat.

Sommaire

Évaluation du poste de pilotage de l'hélicoptère Bell 412CF

Pierre Meunier; DRDC Toronto TM 2009-160; R & D pour la défense Canada – Toronto; Décembre 2009.

Introduction ou contexte

L'hélicoptère Bell 412CF a récemment été ajouté au programme de formation au pilotage des appareils multi-moteurs, aux équipages composés de plusieurs pilotes et au vol IFR. Neuf hélicoptères Bell 412CF ont été produits à partir d'hélicoptères *Griffon*, ce qui a posé des défis sur le plan technique. Un des défis en question était d'acheminer de volumineux faisceaux de câbles de chaque côté du tableau de bord principal. Certains de ces faisceaux de câbles ont été acheminés à proximité du palonnier, et l'on était préoccupé par le fait qu'ils puissent gêner le fonctionnement des pédales.

Le principal objectif de cette étude était de vérifier si les faisceaux de câbles gênaient le fonctionnement du palonnier alors qu'il est utilisé par des pilotes de différentes statures. Un deuxième objectif consistait à déterminer les limites de l'aménagement du poste de pilotage en ce qui concerne la maîtrise du manche.

Résultats

Les résultats de la présente étude indiquent que, même si cette solution n'est pas idéale, l'acheminement des faisceaux de câbles ne gênera fort probablement pas le fonctionnement du palonnier lorsqu'il est utilisé par le pilote assis dans le siège droit, et ce, dans les pires conditions, c'est-à-dire que le palonnier se trouve tout à fait en position avant, que la pédale gauche est complètement enfoncée et que le pilote porte des bottes d'hiver de pointure 13. Dans l'ensemble, les résultats obtenus auprès d'un petit échantillonnage d'élèves-pilotes indiquent que l'aménagement du poste de pilotage est satisfaisant pour ce qui est de maîtriser le manche. Même si la maîtrise du manche varie d'un élève-pilote à l'autre, la plupart des pilotes devraient pouvoir s'asseoir assez confortablement dans leur siège pour exécuter sans entrave tous les mouvements nécessaires aux manœuvres comprises dans le programme de cours.

Portée

La présence des faisceaux de câbles à proximité du palonnier, même si cette solution n'est pas idéale, ne semble pas gêner le fonctionnement du palonnier qui est utilisé par le pilote assis dans le siège droit.

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Acknowledgements

The author gratefully acknowledges the assistance provided by Dave Mohan of CAE Professional Services in this evaluation.

1 Introduction

The Bell 412CF was recently added to the helicopter training curriculum to teach multi-engine, multi-crew and IFR (Instrument Flight Rules) skills. Nine helicopters were produced from former Canadian Forces (CF) CH-146 Griffons that were "significantly upgraded and re-certified to civilian standards"[1]. The conversion of the Griffons posed technical challenges that, as in any such project, required compromises. One such compromise was the routing of large bundles of electrical wires inside the main instrument panel. Some of these wire bundles were routed very close to the rotor pedals, as visible in Figure 1, causing concerns about potential interference with their operation.

The primary purpose of this study was to investigate the potential interference of the wire bundles with the operation of the rotor pedals for a range of operator sizes. A second objective was to determine the limits of accommodation of the cockpit with respect to stick authority.

This report documents the assessment that took place in March 2009 at the Contracted Flying Training and Support (CFTS) in Southport, Manitoba.

Figure 1 Left seat pedals versus wire bundles routing

[1] http://www.airtraining.forces.gc.ca/training/fmt/canadawings_bell412cf_e.asp

2 Method

2.1 Subjects

Eleven subjects were recruited from the pool of students present at 3 Canadian Forces Flying Training School (CFFTS). The anthropometric characteristics of the personnel were obtained from the database of their measurements taken during the recruitment process. Stature and weight, as well as seated height and buttock-knee length were used as selection variables. The subjects were selected in such a way as to cover as much of the variability encountered in the CF as possible. Figure 2 shows that this was accomplished relatively well in terms of stature and weight relative to the 1997 (LF97) survey of the land forces (Chamberland, Carrier, Forest, & Hachez, 1998). However, this was not the case with respect to seated height and buttock-knee length, as shown in Figure 3, where all subjects appeared to be of similar torso to leg length proportions. It should be noted that the 1997 survey was used as a reference for comparative purposes, as it represents the most complete and up to date source of male and female anthropometric data in the CF.

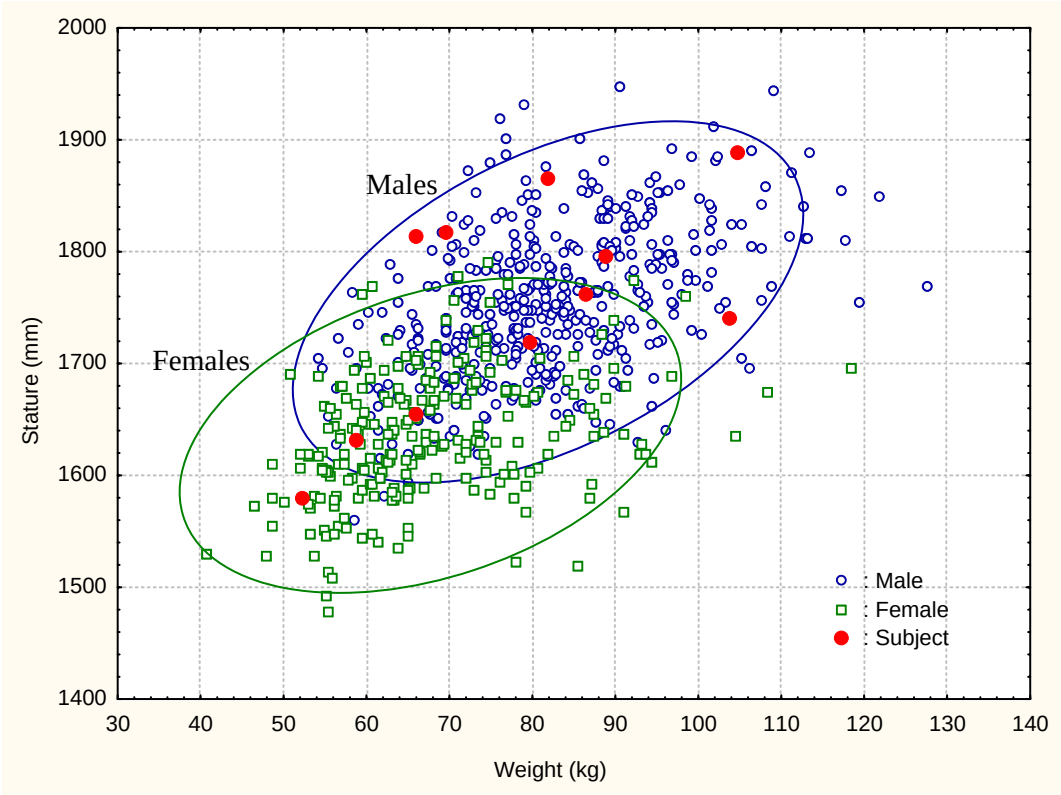


Figure 2 Stature and weight of subjects relative to LF97 survey - 95% probability ellipses shown

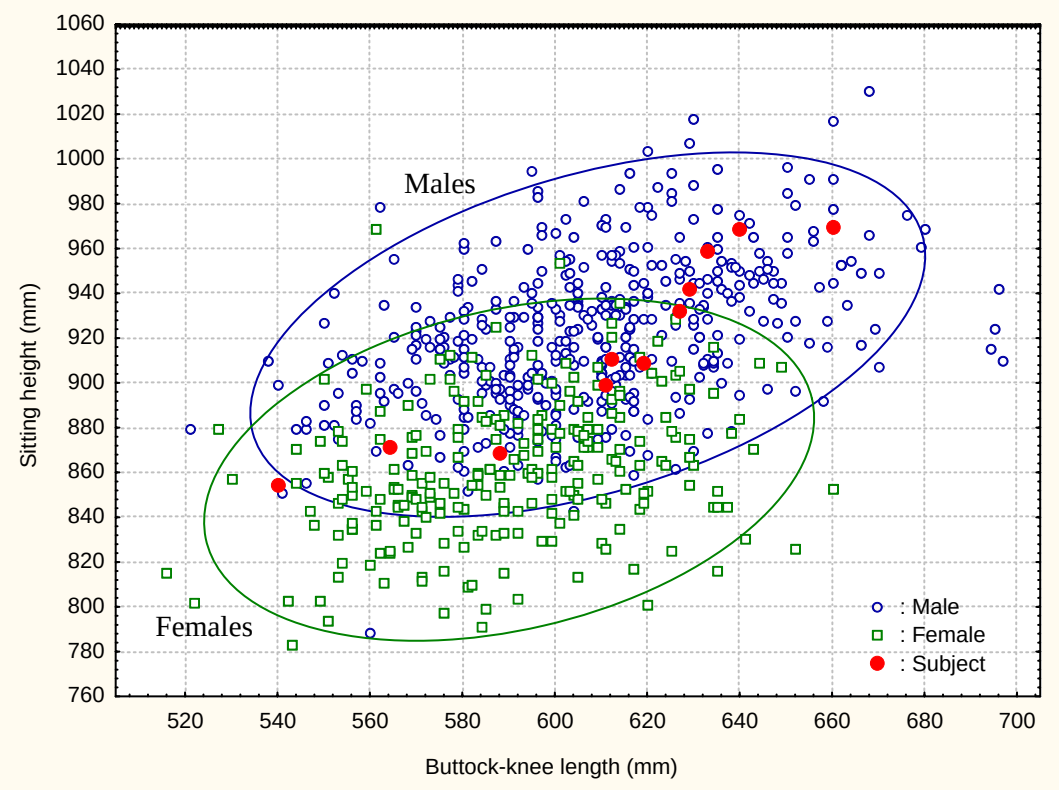


Figure 3 Sitting height versus buttock-knee length relative to LF97 survey - 95% probability ellipses shown

2.2 Test protocol

The participants were measured anthropometrically (see Appendix A), after which they proceeded to the aircraft. The subjects, who were strapped into the left seat, were positioned aft and down and dressed in summer flying clothing. Stick authority was measured in forward left and right, neutral left and right, aft left, centre and right. The displacement of the stick was measured relative to the aircraft structure. The measurements were repeated in the seat aft-up and forward-up positions. The wire bundle routing has the potential to interfere with the pilot's feet during full-right pedal actuation. However, based on discussions with some instructor pilots, full-right rotor pedal actuation is seldom, if ever, used and therefore poses little or no risk. Hence, it was decided that interference measurements were only required in the right seat.

The participants then moved to the right seat, where stick authority measurements were repeated in the same sequence of seat positions as in the left seat. In addition to this, the minimal distance between the boot and the surrounding wires, tubes and pipes was measured with full-left rotor pedal deflection. Full-left rotor deflection is shown in Figure 4.

The participants were asked to don their winter coverall and jacket before repeating the entire sequence of left seat and right seat testing.

Figure 4 Full-left rotor pedal actuation from right seat

3 Results and discussion

3.1 Rotor pedal foot clearance

All of the test participants were able to get full-left rotor pedal deflection, independent of their anthropometry or seat position. As expected, only those who require a full-forward rotor pedal carriage position run the risk of touching the wire bundle. Furthermore, only a subset of those individuals is susceptible to contacting the wire bundle with their boot, as shown in Figure 5, but not enough to impede full deflection. The largest individual, who wore Size 13 boots, was able to clear the bundle depending on how he placed his feet on the pedals.

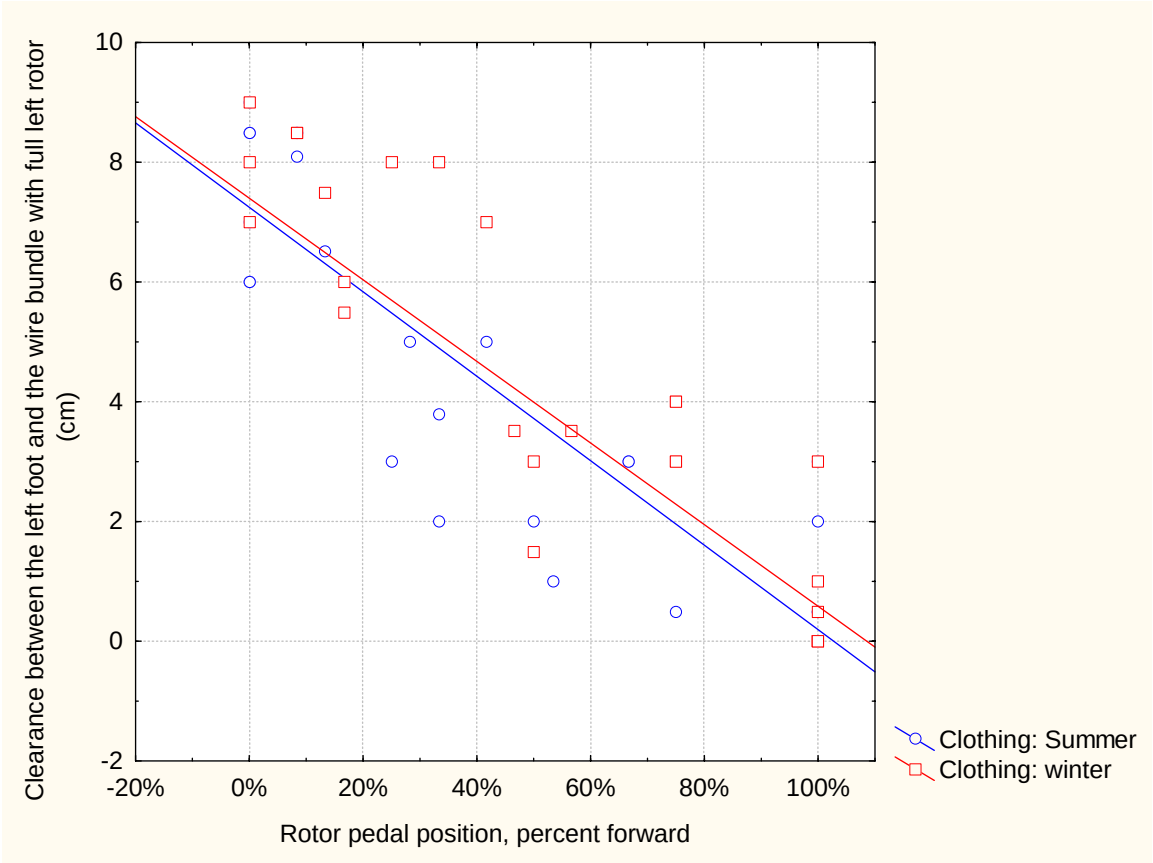


Figure 5 Clearance between the left foot and the wire bundle as a function of rotor carriage position in the right seat, full-left pedal deflection

3.2 Stick authority

The stick authority results are summarized in Figure 6 and Figure 7 for summer and winter clothing, respectively. The histograms depict the left (negative) and right (positive) range of motion of the stick as a percentage of full authority, for neutral and aft longitudinal stick position, in both seats. Forward stick authority is not represented in the figures because it was always 100%.

The results show that, from the right seat, neutral-left and right stick authority is unimpeded (100%) in summer and winter clothing. As illustrated in Figure 6, interference was noted in 36% of the cases in the left seat position, where occupants were only able to obtain between 60% and 80% of the full range of motion of the stick.

The aft-left and right stick authority results (Figure 6 and Figure 7) show that full authority was achieved by most test subjects in the right seat, with only one being unable to attain 100% in summer clothing, and two in winter clothing. Similar results were obtained for the left seat. A reduction in range of stick motion was apparent in winter clothing in the aft left and right quadrants.

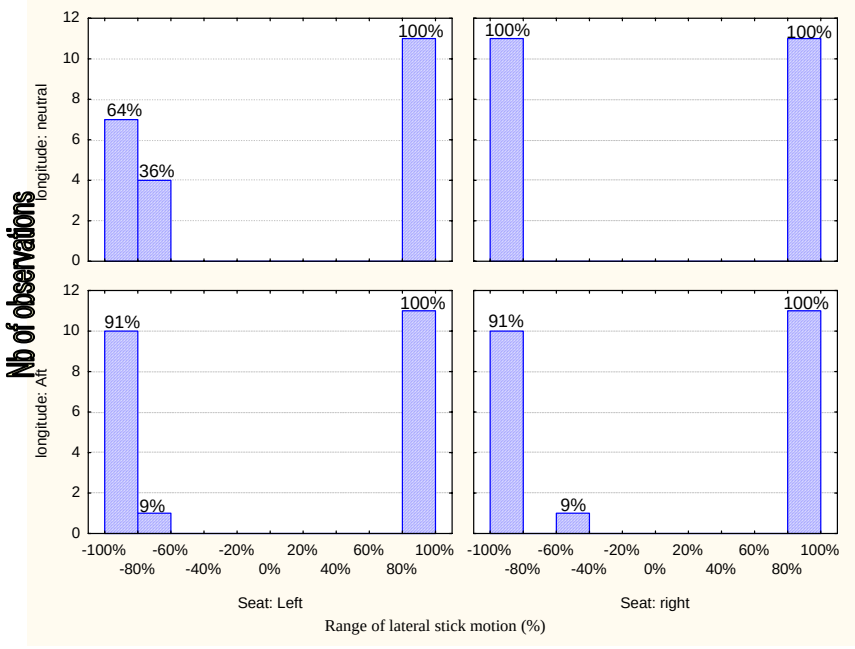


Figure 6. Stick authority in summer clothing, seat aft-down

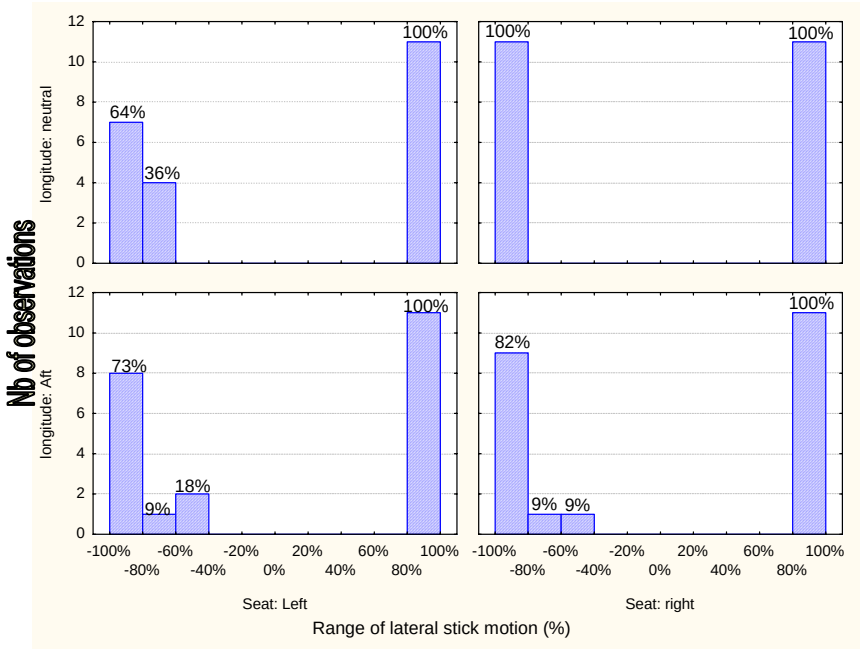


Figure 7. Stick authority in winter clothing, seat aft-down

4 Conclusions

The results of this study indicate that the routing of the wire bundles on either side of the main instrument panel is unlikely to impede operation of the rotor pedals when operated from the right seat in the worst-case situation, namely with the pedal carriage fully forward with full-left pedal actuation with Size 13 winter boots. In the left seat, the wire bundle routing situation is different, as it has the potential to interfere with the pilot's feet during full-right pedal actuation. However, based on discussions with some of the instructor pilots, full-right rotor pedal actuation is seldom, if ever, used and therefore poses little or no risk.

Stick authority results showed that neutral-left stick range of motion was less than 100% in about 36% of the cases, but above 60% in the worst-case scenario, namely when flying from the left seat. No such restrictions were found when flying from the right seat.

Aft-left stick authority was impeded by the thighs in a minority of cases (9% or one test subject). It was above 60% in summer clothing from the left seat and between 40% and 60% from the right seat. The effect of winter clothing, while imperceptible for neutral-left and -right stick authority, was noticeable for aft-left and -right stick authority.

Overall, the results obtained from this small sample of student pilots indicate a fairly accommodating cockpit in terms of stick authority. Although individual students will experience differing degrees of stick authority, the vast majority should be able to find a seat position that will allow ample range of motion to carry out course syllabus manoeuvres.

References

Chamberland, A., Carrier, R., Forest, F., & Hachez, G. (1998). *Anthropometric survey of the Land Forces (LF97)* (Contractor report No. 98-CR-15). Toronto, Ontario: Defence and Civil Institute of Environmental Medicine.

Appendix A - Anthropometric data

Table 1 Anthropometry of subjects in millimeter (except for weight)

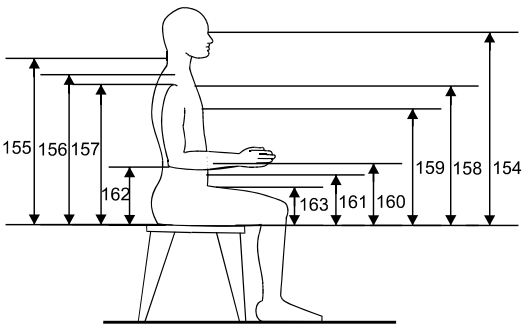
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
Weight (kg)	79.5	88.6	58.6	52.3	86.4	81.8	69.5	65.9	103.6	104.5	65.9
Stature	1719	1797	1632	1580	1763	1866	1818	1814	1742	1889	1656
Thigh circumference, upper	636	705	598	551	632	588	554	519	665	685	534
Thigh circumference, lower	420	443	380	357	408	415	369	348	465	442	352
Functional reach	782	778	697	673	786	820	796	777	785	806	693
Span	1765	1845	1660	1540	1868	1969	1839	1814	1825	1879	1720
Sitting height	899	969	869	855	909	959	932	942	911	970	872
Eye height sitting	776	844	766	745	801	835	809	822	804	857	760
Acromial height sitting	597	643	602	555	590	623	608	600	598	652	553
Knee height	529	544	481	483	557	595	570	564	548	588	506
Biacromial breadth	394	415	380	354	414	410	402	385	404	415	382
Bideltoid breadth	500	490	421	400	502	487	461	466	545	524	461
Hip breadth	365	425	352	334	389	360	340	338	396	392	323
Waist depth	214	268	201	176	255	216	211	212	279	313	196
Buttock-knee length	611	640	588	540	619	633	627	629	612	660	564

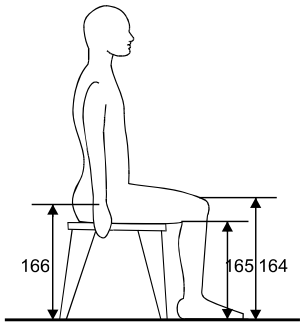
Table 2 Foot-related variables

Subject	1	2	3	4	5	6	7	8	9	10	11
Gender	m	m	f	f	m	m	m	m	m	m	m
Boot size	260-110	8.5 E	240/90	240/94	270/106	275/104	7.5-8 F	10	10.5	300/114	245/100
Boot length	31.5	30	28	28.3	31	31.5	29.9	30.9	30.9	35.5	29
Boot breadth	12	10.9	10.5	10.4	12	11.5	10.6	11.3	11.5	13	10.9
Foot length	25.5	26.5	24.9	22.5	27	27.3	26.7	27	26.6	30	24.3
Foot breadth	10.5	10.7	9	8.6	10.4	10.4	9.4	9.7	10	11.6	9.4

Definitions

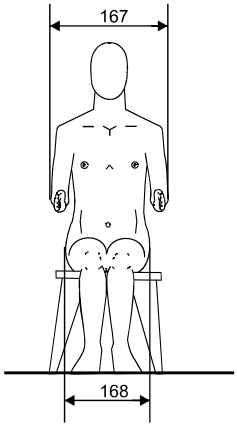
The following are a few of measurement definitions used in this study (taken from (Chamberland et al., 1998)).

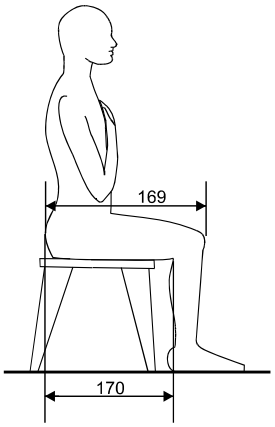


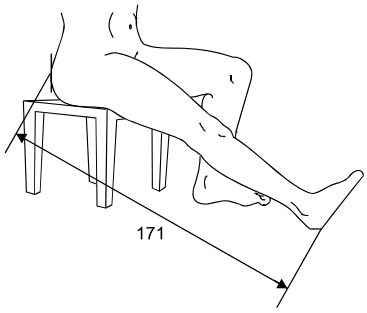


154- Eye height sitting / Hauteur yeux assis
155- Cervicale height sitting / Hauteur cervicale assis
156- Midshoulder height sitting / Hauteur mi-épaule assis
157- Acromion height sitting / Hauteur acromion assis
158- Suprasternale height sitting / Hauteur supra-sternale assis
159- Chest height sitting / Hauteur thélion assis
160- Waist height sitting (nat.ind.) / Hauteur taille assis

161- Waist height sitting (omph.) / Hauteur omphalion assis
162- Elbow rest height / Hauteur coude assis
163- Thigh clearance / Hauteur encombrement cuisse
164- Knee height sitting / Hauteur genou assis
165- Popliteal height / Hauteur poplité
166- Wrist height sitting /Hauteur poignet assis







167- Forearm-forearm breadth / Largeur avant-bras - avant-bras
168- Hip breadth sitting / Largeur hanches assis
169- Buttock-knee length / Portée arrière genou assis

170- Buttock-popliteal length / Portée arrière creux poplité
171- Functional leg length / Longueur fesse-pied

Sitting Height (4)

The vertical distance between a sitting surface and the top of the head is measured with an anthropometer. The subject sits erect with the head in the Frankfort plane. The shoulders and upper arms are relaxed and the forearms and hands are extended forward horizontally with the palms facing each other. The thighs are parallel and the knees are flexed 90 degrees with the feet in line with the thighs. The measurement is made at the maximum point of quiet respiration.

Eye Height, Sitting (154)

The vertical distance between a sitting surface and the ectocanthus landmark on the outer comer of the right eye is measured with an anthropometer. The subject sits erect with the head in the Frankfort plane. The shoulders and upper arms are relaxed and the forearms and hands are extended forward horizontally with the palms facing each other. The thighs are parallel and the knees are flexed 90 degrees with the feet in line with the thighs. The measurement is taken at the maximum point of quiet respiration.

Acromial Height, Sitting (157)

The vertical distance between a sitting surface and the acromion landmark on the tip of the right shoulder is measured with an anthropometer. The subject sits erect looking straight ahead. The shoulders and upper arms are relaxed and the forearms and hands are extended forward horizontally with the palms facing each other. The measurement is made at the maximum point of quiet respiration.

Knee Height, Sitting (164)

The vertical distance between a footrest surface and the suprapatella landmark at the top of the right knee (located and drawn while the subject stands) is measured with an anthropometer. The subject sits with the thighs parallel, the knees flexed 90 degrees, and the feet in line with the thighs.

Buttock-Knee Length (169)

The horizontal distance between a buttock plate placed at the most posterior point on either buttock and the anterior point of the right knee is measured with an anthropometer. The subject sits erect. The thighs are parallel and the knees flexed 90 degrees with the feet in line with the thighs.

Functional Leg Length (171)

The straight-line distance between the plane of the bottom of the right foot with the leg extended and the back of the body of a seated subject is measured with an anthropometer passing over the trochanter landmark on the side of the hip. The subject sits erect on a stool 40.8 cm high. The right leg is extended and the foot is on the base plate of the anthropometer, which rests on the floor. The measurement is made from the footrest surface of the base plate.

List of symbols/abbreviations/acronyms/initialisms

CF	Canadian Forces
CFFTS	Canadian Forces Flying Training School
CFTS	Contracted Flying Training and Support
IFR	Instrument Flight Rules

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(U) The Bell 412CF helicopter was recently added to the training curriculum to teach multi–engine, multi–crew and IFR skills. Nine Bell 412CF helicopters were produced from existing Griffons, which posed technical challenges. One such compromise was the routing of large bundles of wires either side of the main instrument panel. Some of these wire bundles were routed very close to the rotor pedals causing concerns about potential interference with their operation.

The results of this study indicate that the routing of the wire bundles, while not ideal, is unlikely to impede operation of the rotor pedals when operated from the right seat in the worst–case situation, namely with the pedal carriage fully forward with full left pedal actuation with size 13 winter boots. Overall, the results obtained from this small sample of student pilots indicate a fairly accommodating cockpit in terms of stick authority. Although individual students will experience differing degrees of stick authority, the vast majority should be able to find a seat position that will allow ample range of motion to carry out course syllabus manoeuvres.

(U) L'hélicoptère Bell 412CF a récemment été ajouté au programme de formation au pilotage des appareils multimoteurs, aux équipages composés de plusieurs pilotes et au vol IFR. Neuf hélicoptères Bell 412CF ont été produits à partir d'hélicoptères Griffon, ce qui a posé des défis sur le plan technique. Un des défis en question était d'acheminer de volumineux faisceaux de câbles de chaque côté du tableau de bord principal. Certains de ces faisceaux de câbles ont été acheminés à proximité du palonnier, et l'on était préoccupé par le fait qu'ils puissent gêner le fonctionnement des pédales.

Les résultats de la présente étude indiquent que, même si cette solution n'est pas idéale, l'acheminement des faisceaux de câbles ne gênera fort probablement pas le fonctionnement du palonnier lorsqu'il est utilisé par le pilote assis dans le siège droit, et ce, dans les pires conditions, c'est–à–dire que le palonnier se trouve tout à fait en position avant, que la pédale gauche est complètement enfoncée et que le pilote porte des bottes d'hiver de pointure 13. Dans l'ensemble, les résultats obtenus auprès d'un petit échantillonnage d'élèves–pilotes indiquent que l'aménagement du poste de pilotage est satisfaisant pour ce qui est de maîtriser le manche. Même si la maîtrise du manche varie d'un élève–pilote à l'autre, la plupart des pilotes devraient pouvoir s'asseoir assez confortablement dans leur siège pour exécuter sans entrave tous les mouvements nécessaires aux manœuvres comprises dans le programme de cours.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

(U) Cockpit accommodation, anthropometry

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